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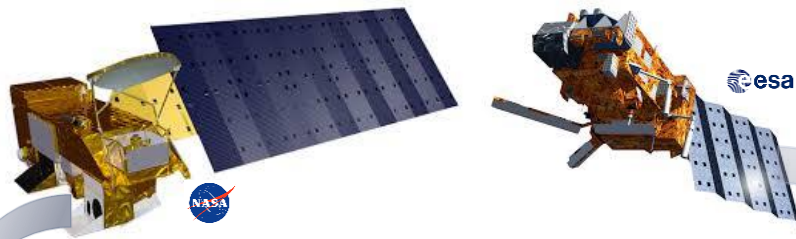
# Satellite data assimilation of dust aerosol observations for the MONARCH forecasting system

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Oriol Jorba, Carlos Pérez García-Pando, Francesca  
Macchia

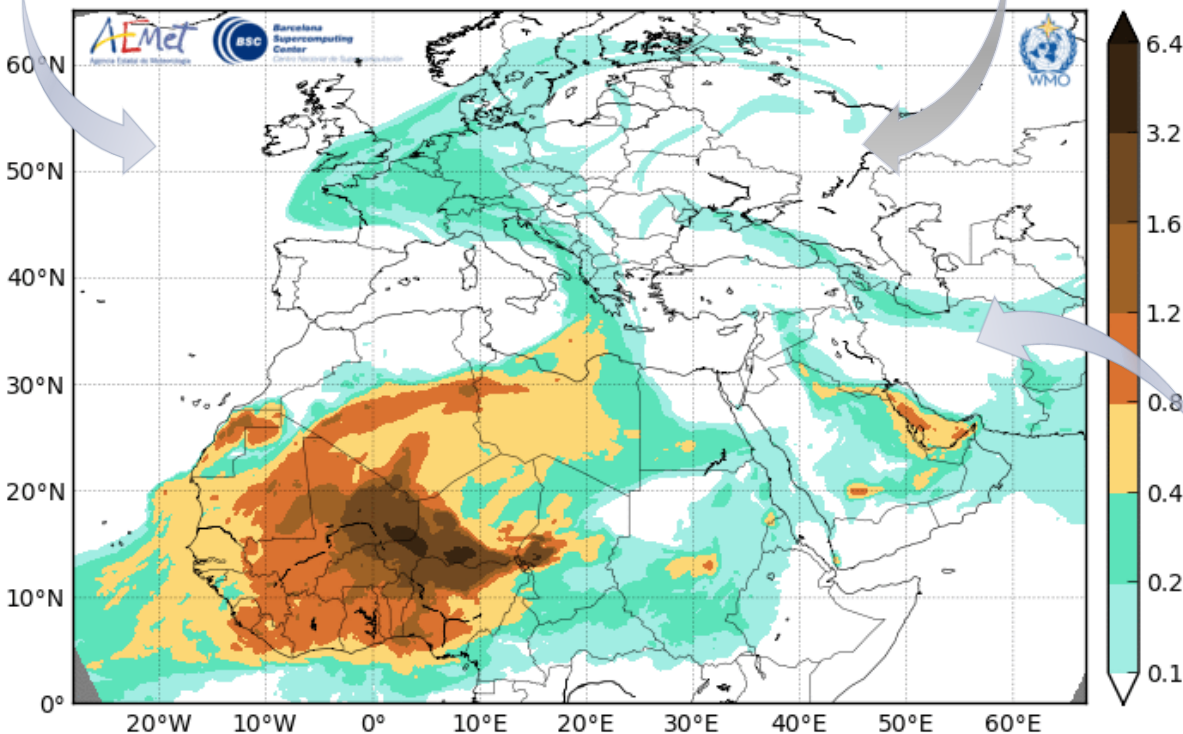
17/05/2019

Living Planet Symposium 2019, Milano, Italy

# Constraining Mineral Dust Simulations with Observations



Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
NMMB/BSC-Dust Res:0.1°x0.1° Dust AOD  
Run: 12h 09 APR 2018 Valid: 12h 09 APR 2018 (H+00)



**Model simulations and observations** are combined to obtain the 'best' estimate of current atmospheric conditions (dust analysis)



# Motivation

Assess the potential benefit of dedicated dust observation products in dust data assimilation

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*Operational **dust forecast** and **dust reanalyses** are produced in the framework of aerosol data assimilation, where **total AOD** is used to constrain all the main aerosol species*

# Experiment design



control simulation

Dust component of the NMMB-MONARCH chemical weather system (Pérez et al., 2011)

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ensemble forecast

NMMB-MONARCH ensemble members are obtained taking into account model and IC/BC uncertainty

# Experiment design



control simulation

Dust component of the NMMB-MONARCH chemical weather system (Pérez et al., 2011)

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ensemble forecast

NMMB-MONARCH ensemble members are obtained taking into account model and IC/BC uncertainty

Role of the ensemble (B matrix):

- spatial spreading of information from observations
- statistically consistent increments between neighbouring grid points
- multivariate analysis

# Experiment design



data assimilation

- An ensemble-based DA scheme: LETKF
- usage of a flow-dependent background error covariance
  - performing the analysis locally
-



# Experiment design



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  - performing the analysis locally
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observations

Dedicated dust observations:

- MODIS Dark Target AOD in dust-dominated conditions
- MODIS Deep Blue AOD in dust-dominated conditions
- IASI dust AOD
- ACTRIS lidar dust extinction coefficient profiles

# MODIS Dark Target and Deep Blue, Level3



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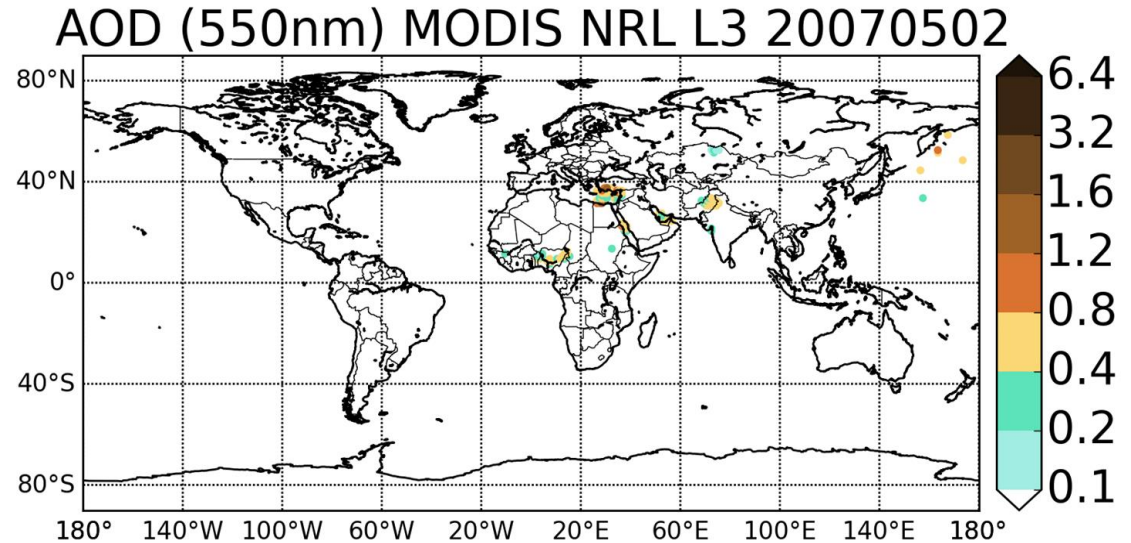
# Assimilated observations

## NRL MODIS Dark Target, L3 C5

- filtered and corrected,
- spatially aggregated,
- uncertainty estimation

(*Zhang and Reid, 2006; Hyer et al., 2010; Shi et al., 2011*)

- AE, AI filter for dust

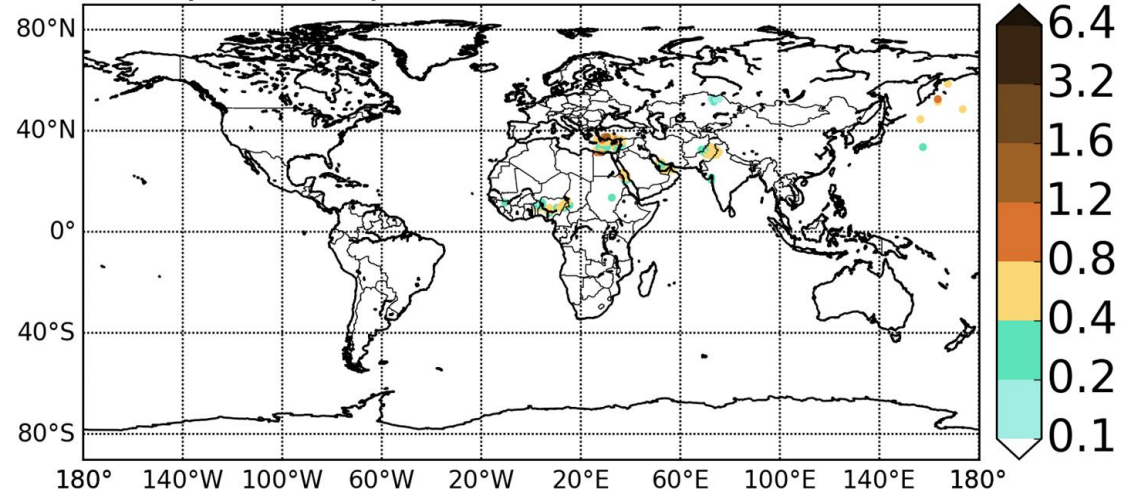


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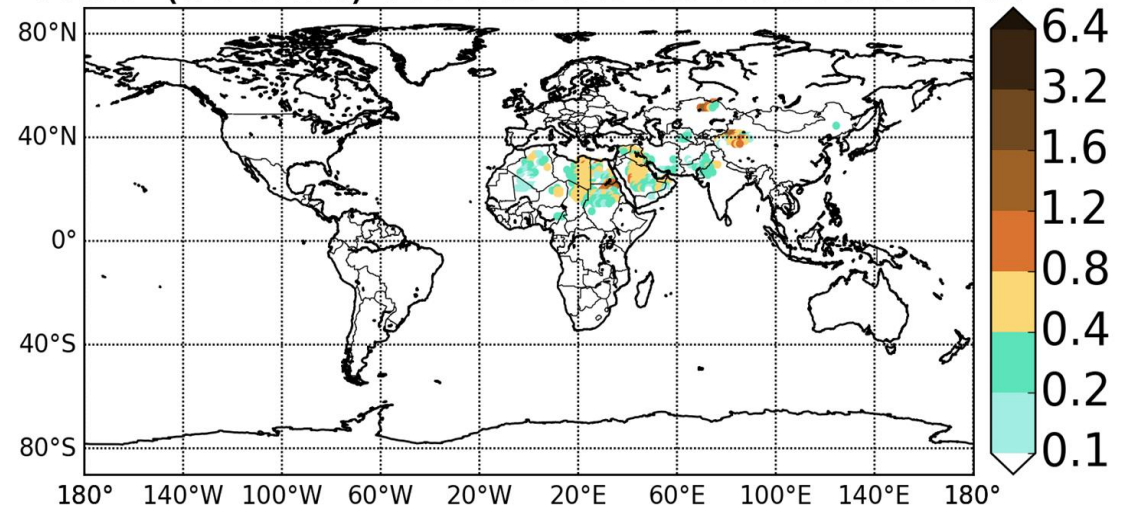
AOD (550nm) MODIS NRL L3 20070502



## MODIS Deep Blue, L3 C6

- aggregation of highest quality L2
- uncertainty model for L2  
(*Sayer et al., 2014*)
- AE, AI, counts filter
- uncertainty model for L3:  
 $\sigma_m^2 + \sigma_r^2$

AOD (550nm) MODIS DB L3 2007050212

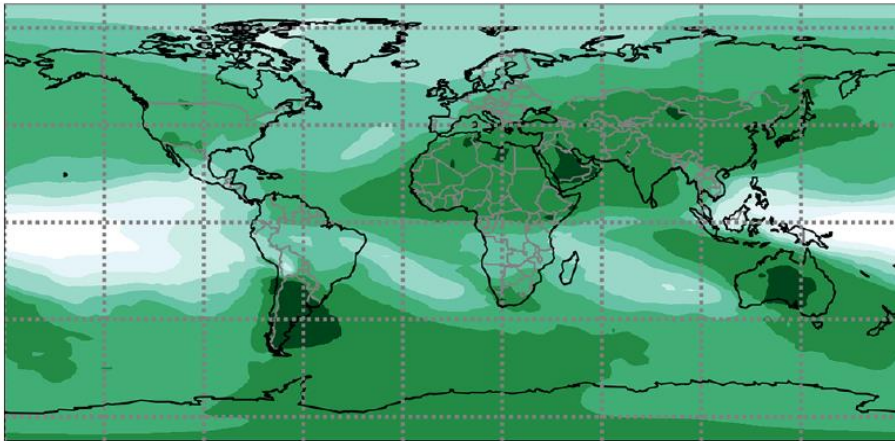




# Ensemble Spread Reduction

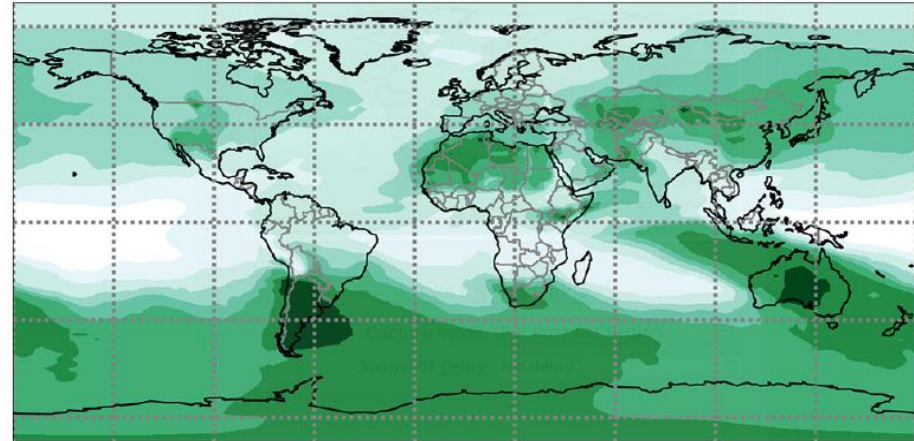
Ensemble free run

Dust AOD (550 nm) CV, ENS-free-run



Data assimilation run

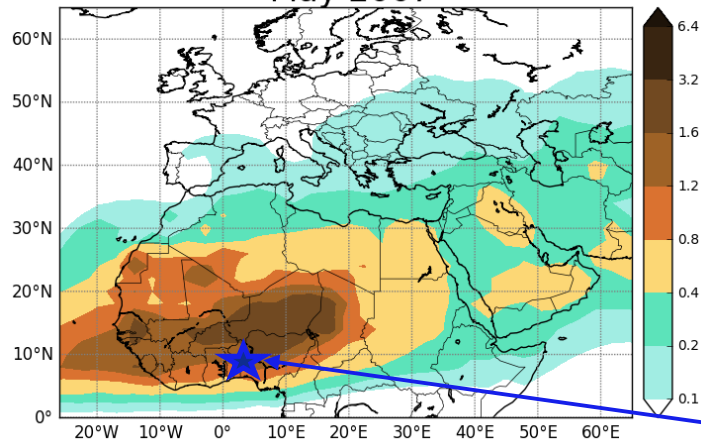
Dust AOD (550 nm) CV, DA-NRL-DB



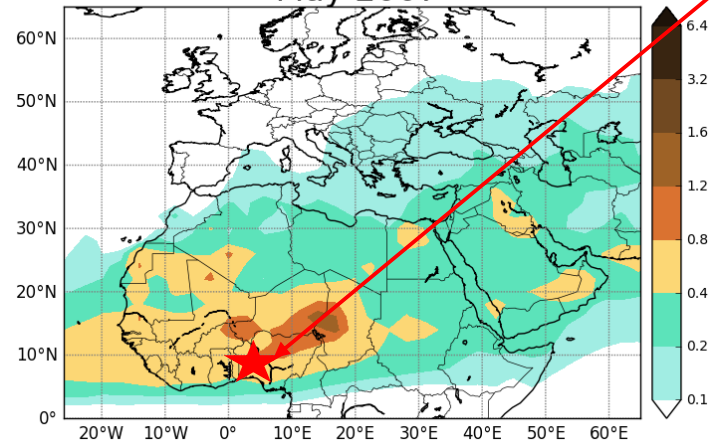
Data assimilation lowers the values of the coefficient of variation in the regions where observations are present, which indicates a reduction of the ensemble spread due to the assimilated observations

# Validation of the forecast

Dust AOD (550nm), Control Simulation  
May 2007

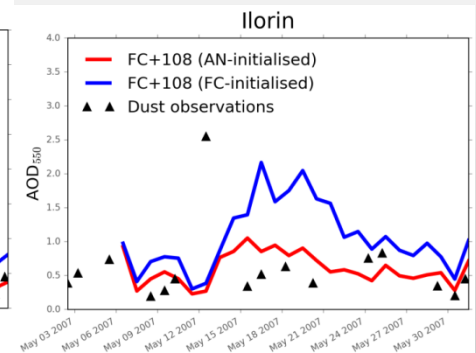
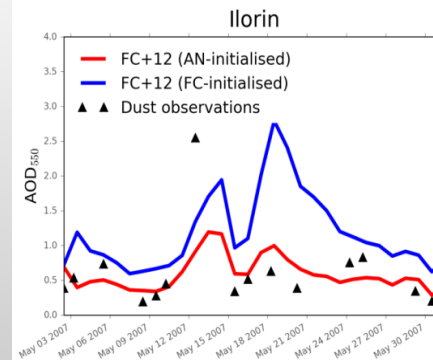
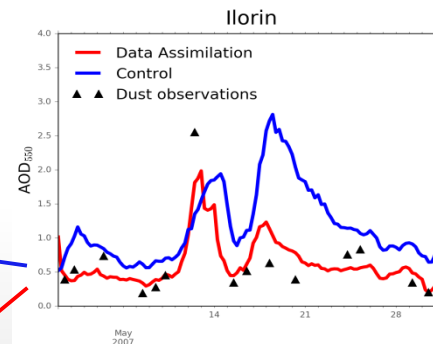


Dust AOD (550nm), DA Simulation  
May 2007



## Validation

Better description of  
current and forecast  
conditions for dust  
with data assimilation



*AERONET site of independent sun photometer observations*

# MODIS Deep Blue, Level 2



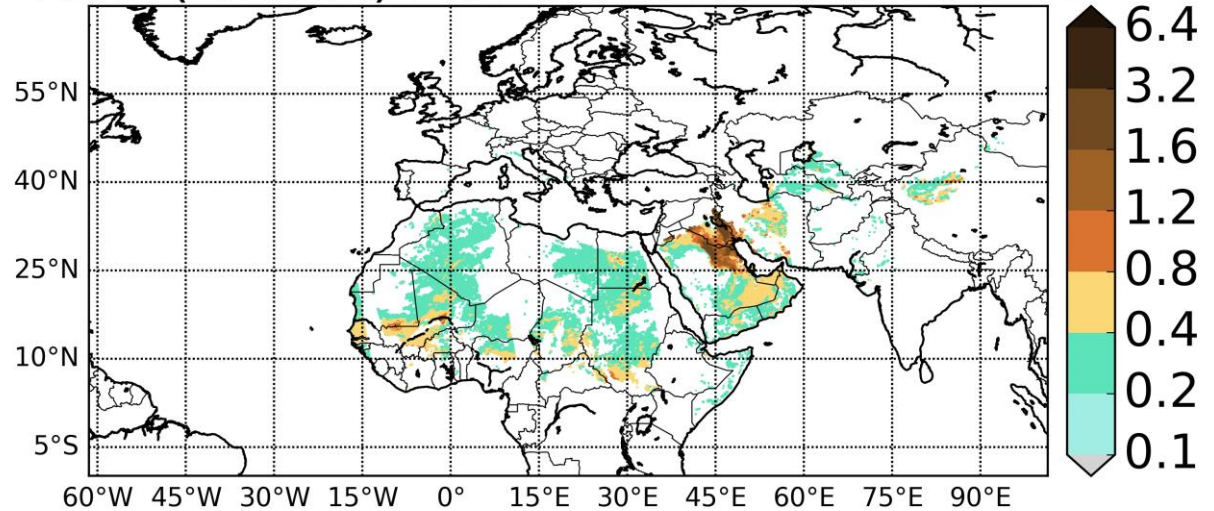
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# Assimilated observations

AOD (550nm) MODIS DB \_\_ 2012030112



**MODIS Deep Blue, L2 C6**

- AE,  $\omega$  filter

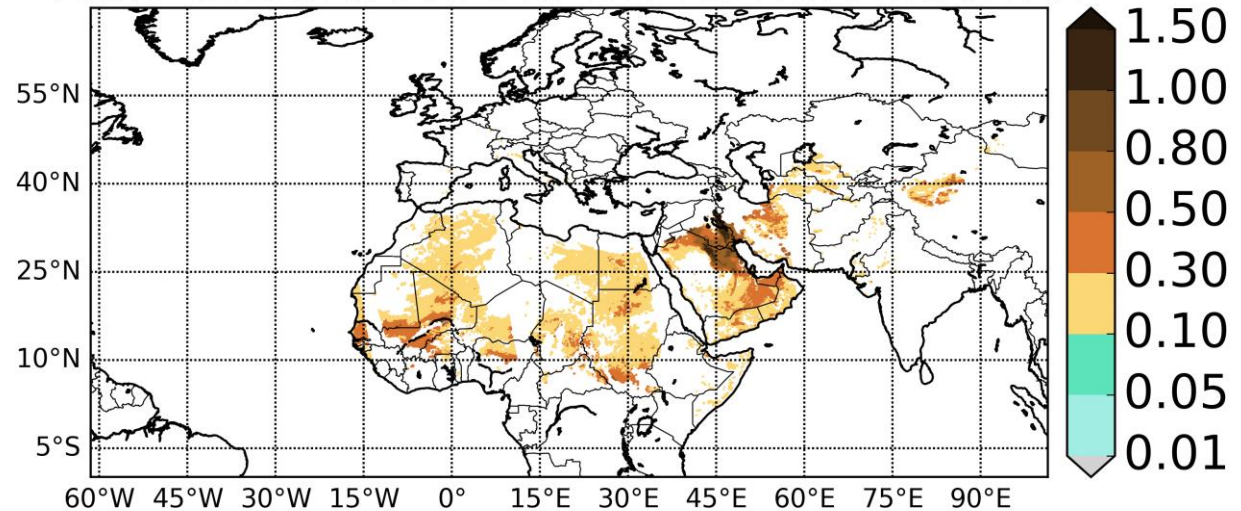
- highest quality flag

(Ginoux et al., 2012)

- uncertainty model based

on Sayer et al., 2014

AOD Uncert. MODIS DB \_\_ 2012030112

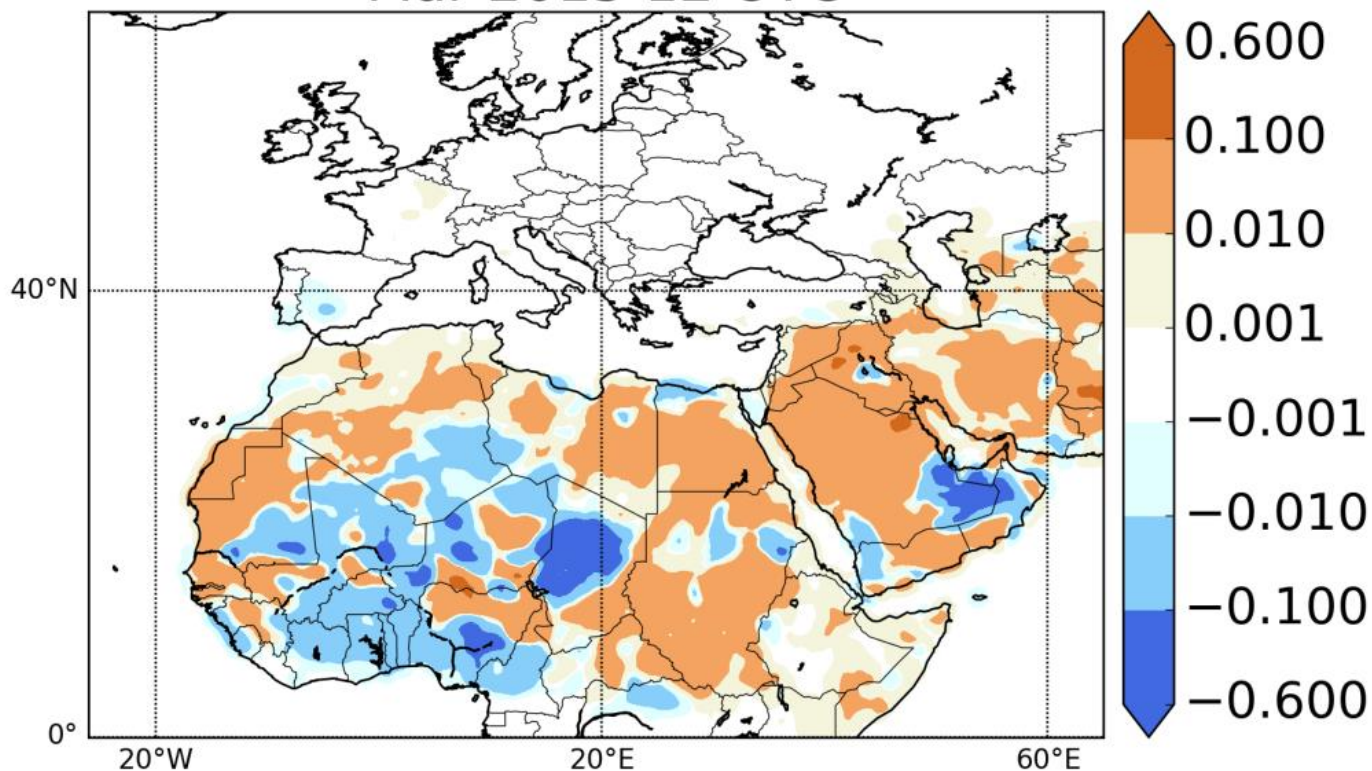




# Analysis increments

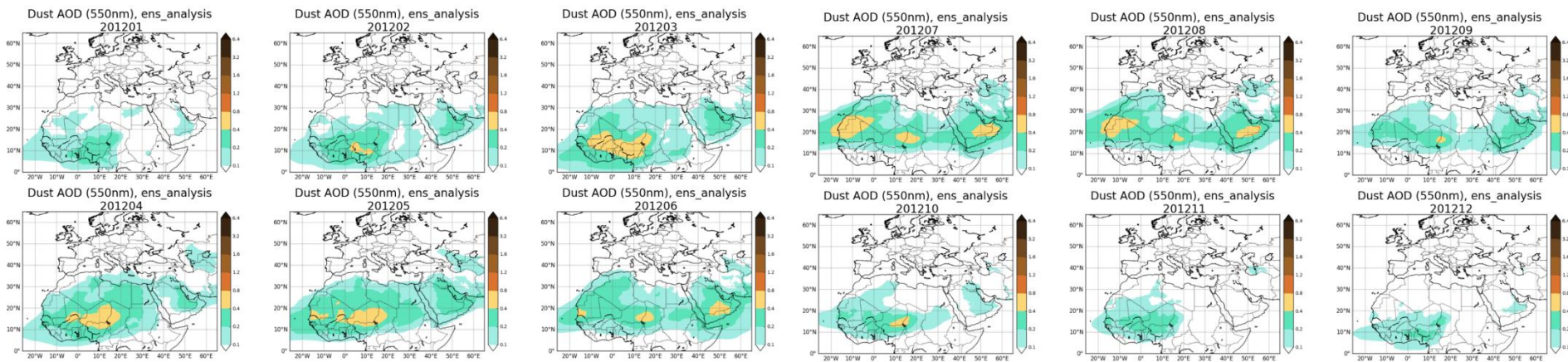
*Feedback from assimilation increments*

Dust AOD (550nm) analysis - first guess  
Mar 2015 12 UTC



Produce a **high resolution dust reanalysis** for Northern Africa, Middle East and Europe covering the satellite era of quantitative aerosol information, and develop **dust-related services** tailored to specific socio-economic sectors

## Monthly dust analyses for 2012



# IASI dust AOD, Level 3



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# Aerosol\_cci and CMUG projects

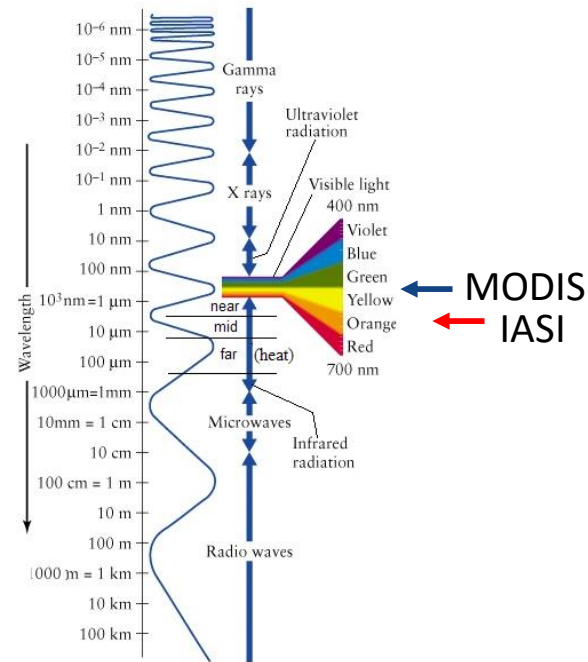


climate change initiative

European Space Agency

## IASI dust AOD

- observations available day time and night time
- over ocean and over land (desert)
- 10  $\mu\text{m}$ : detection of dust aerosol coarse mode (infrared wavelengths and “V” shaped depression of the Brightness Temperature)
- pixel level uncertainty



2006

2012

2018

2021

2028

2035

IASI/  
Metop-A

IASI/  
Metop-B

IASI/  
Metop-

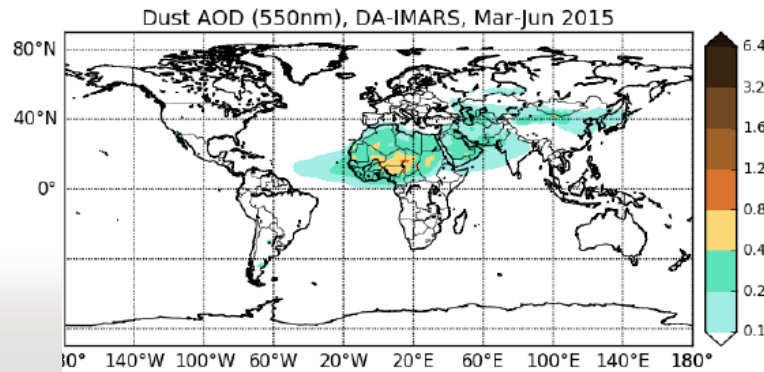
IASI-NG/  
Metop-SG

IASI-NG/  
MetopSG-B

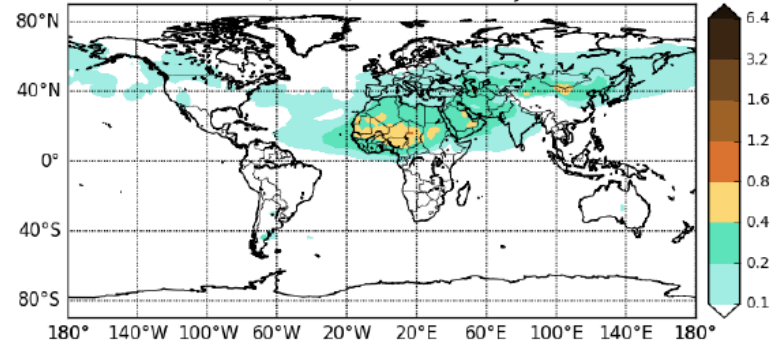
IASI-NG/  
MetopSG-C

# IASI analyses

IMARS



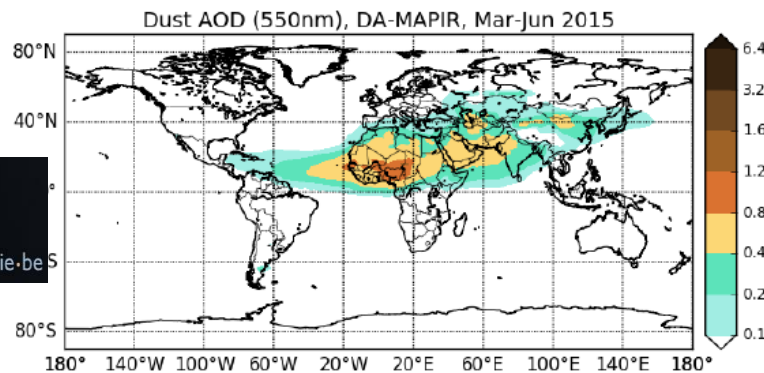
Dust AOD (550nm), DA-LMD, Mar-Jun 2015



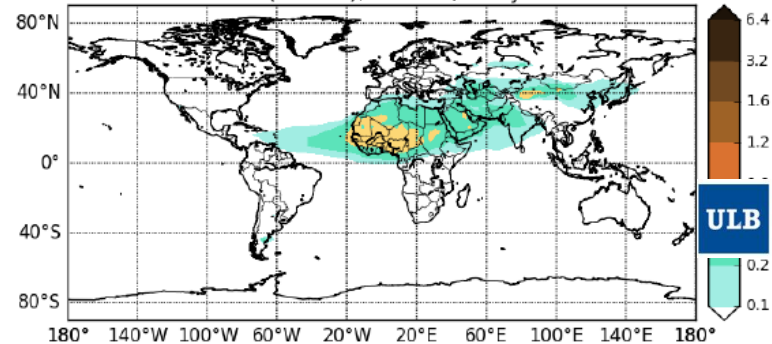
LMD



MAPIR



Dust AOD (550nm), DA-ULB, Mar-Jun 2015



ULB

UNIVERSITÉ  
LIBRE  
DE BRUXELLES

- The seasonal value of AOD is lowered by DA over the strong African sources in all the experiments, with the exception of the MAPIR analysis;
- The LMD analysis stands out for higher AOD values at latitudes above 40 degree north.

# Aerosol, Clouds, and Trace gases (ACTRIS) lidar profiles



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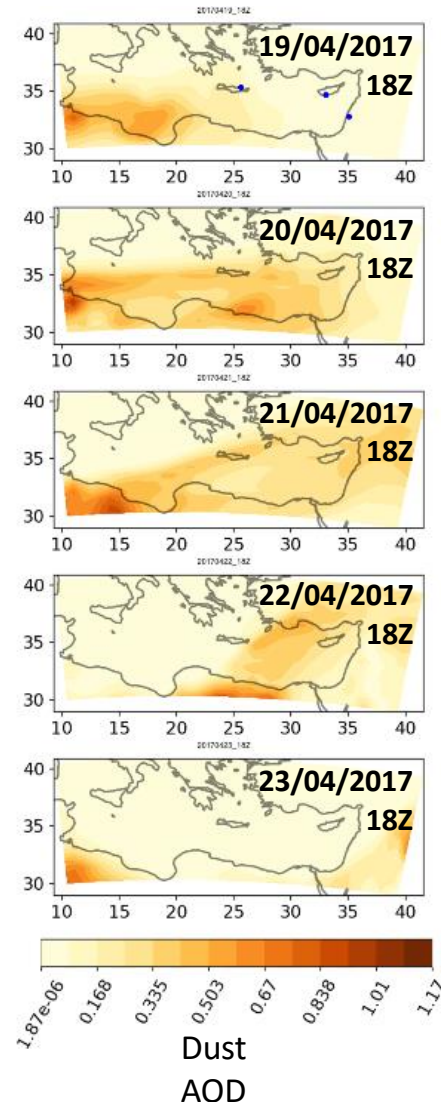


# Evaluating the potential of ACTRIS-2 profiles for DA

- Model simulations from the BSC model (NMMB-MONARCH)
- PollyNet lidar extinction profiles processed by TROPOS



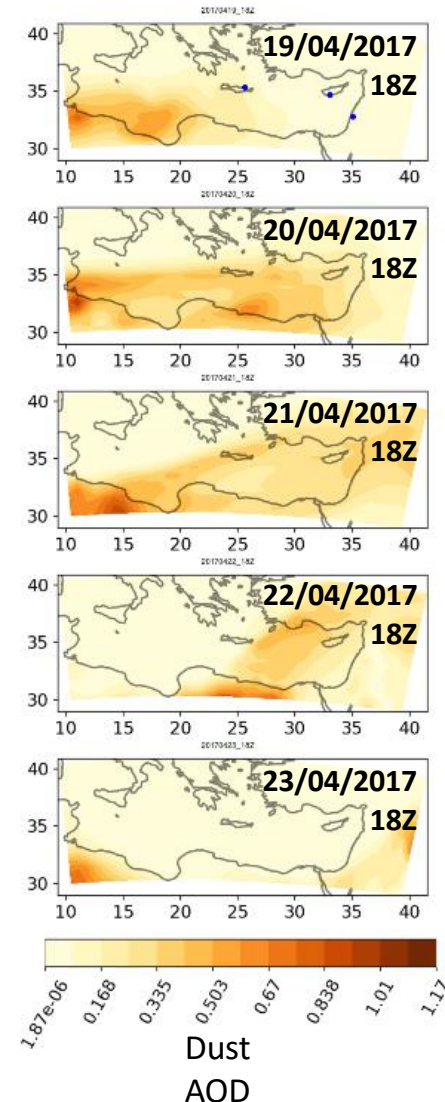
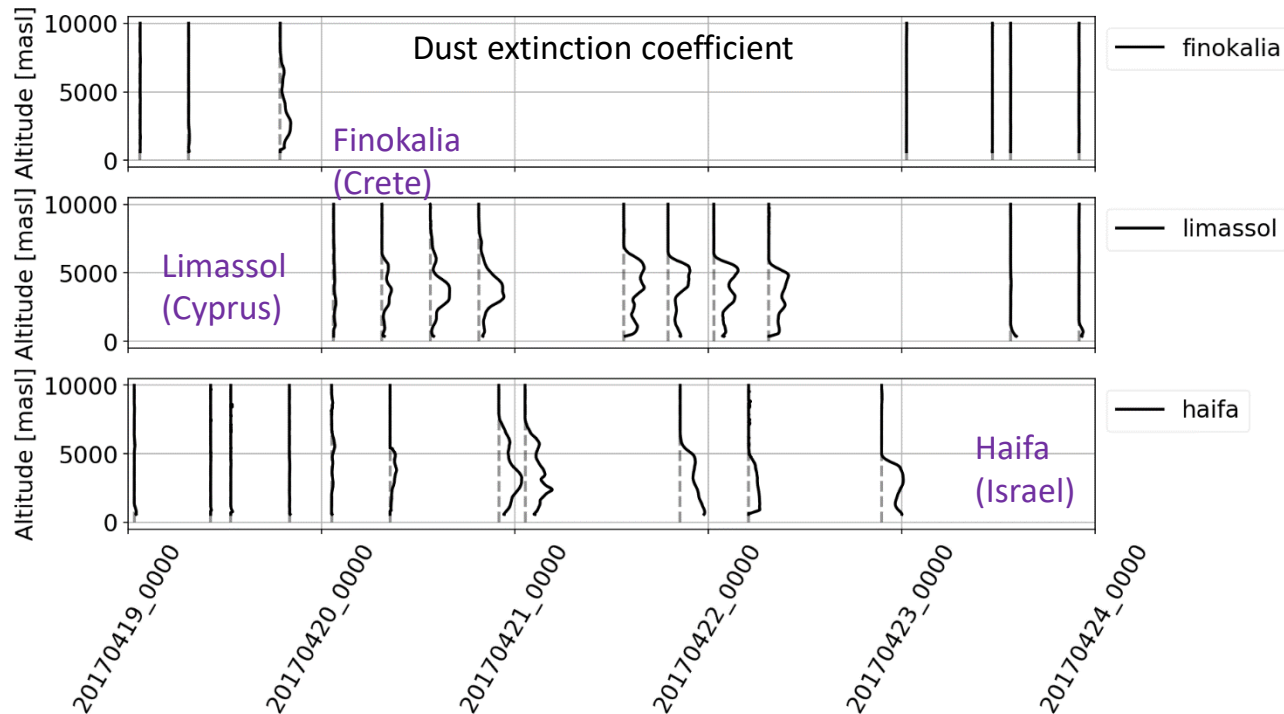
MODIS-Aqua 21/04/2017, NASA



# Evaluating the potential of ACTRIS-2 profiles for DA



Event observed by 3 lidar sensors located in **Finokalia (Crete)**, **Limassol (Cyprus)** and **Haifa (Israel)** part of the PollyNet (<http://polly.tropos.de/>) system. Data (with uncertainty estimation) processed by **TROPOS**.





# Evaluating the potential of ACTRIS-2 profiles for DA



- Model simulations from the BSC model (NMMB-MONARCH)
- PollyNet lidar extinction profiles processed by TROPOS

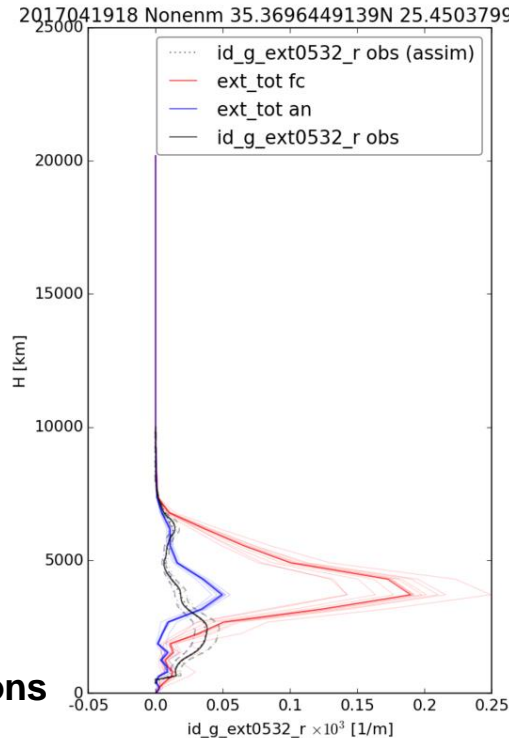
*Case study: 19-23 April 2017*

**Extinction profiles for**

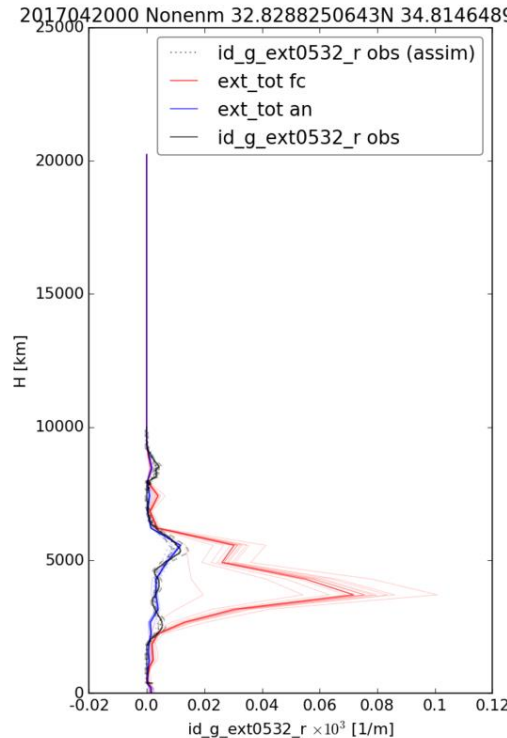
**- ensemble forecast**

**- ensemble analysis**

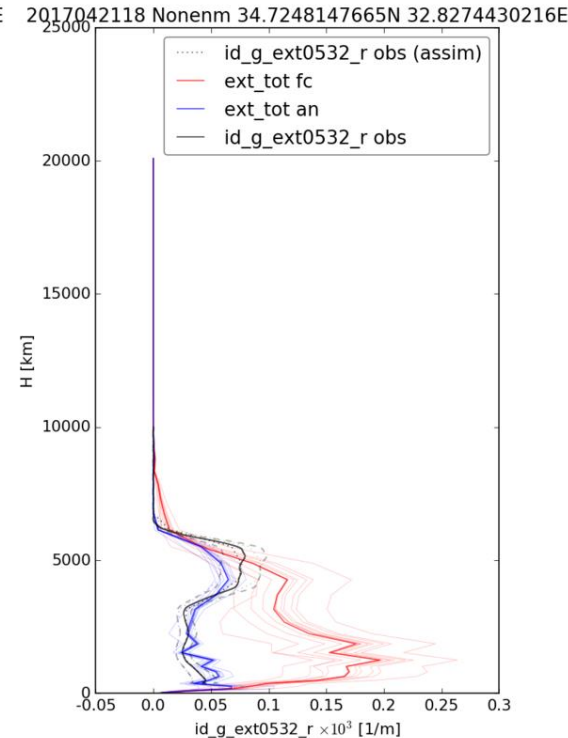
**- observations**



Finokalia (Crete)



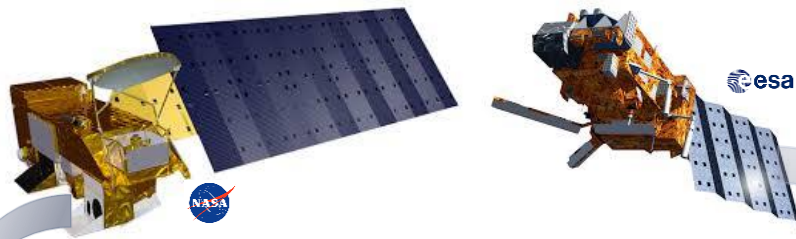
Haifa (Israel)



Limassol (Cyprus)

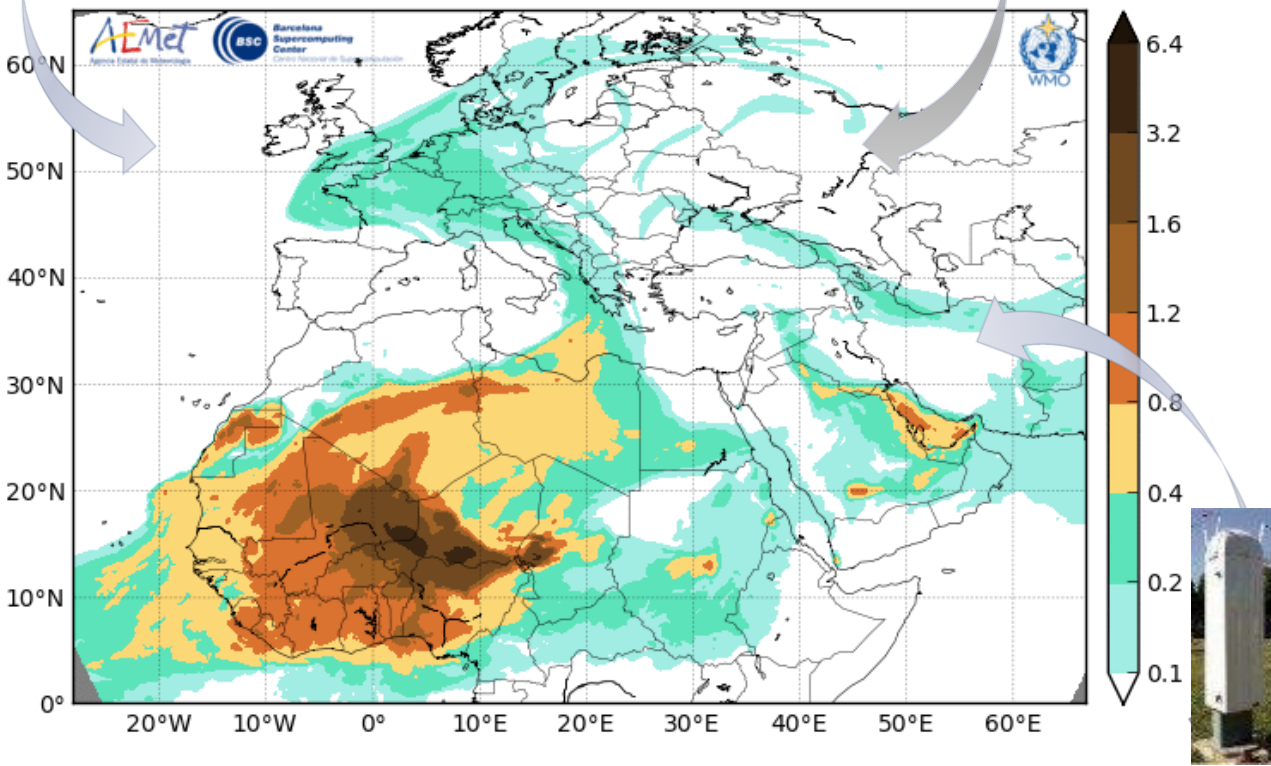
- correction of a model underestimation of the total column extinction
- correction in most cases the plume height

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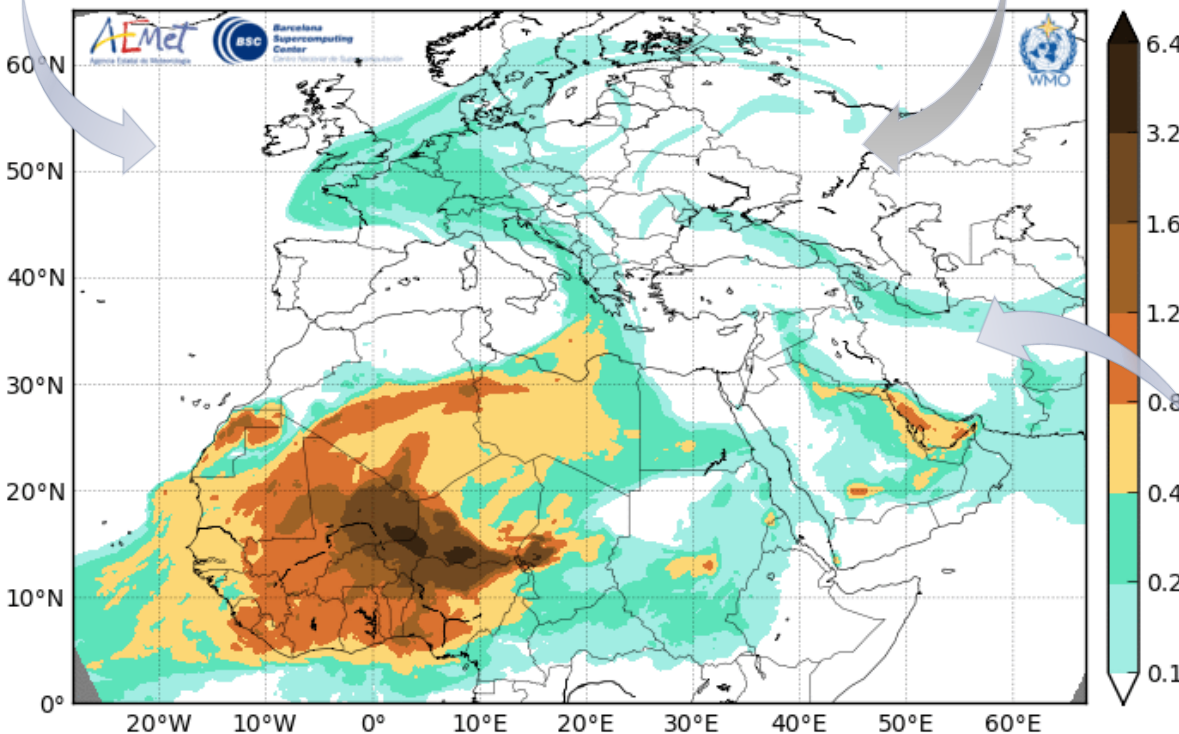
**Model simulations and observations** are combined to obtain the 'best' estimate of current atmospheric conditions (dust analysis)



# Constraining Mineral Dust Simulations with Observations

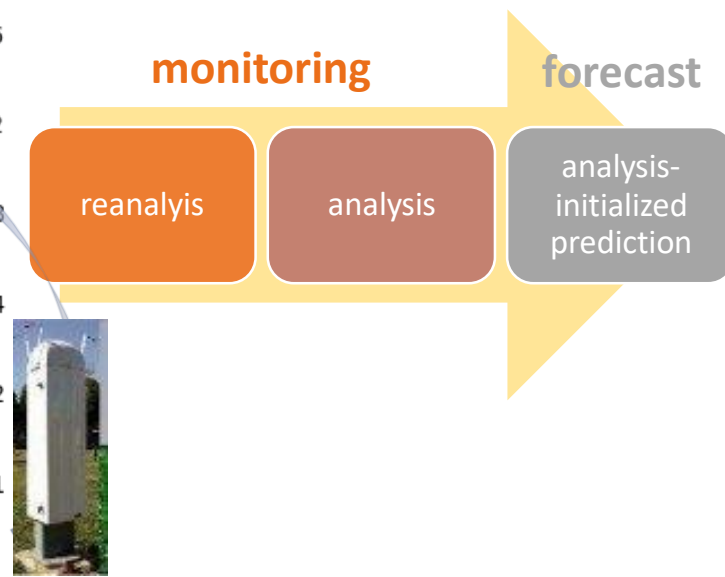


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**Model simulations and observations** are combined to obtain the 'best' estimate of current atmospheric conditions (dust analysis)

- *useful to initialise models and improve predictions*
- *used to produce reanalysis*





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**EXCELENCIA  
SEVERO  
OCHOA**

Thanks to the people taking  
measurements, maintaining  
sites, making retrievals and  
observation products

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